VENOUS RETURN REVIEW

The effects of water immersion on venous return

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Conflict of interest: G Bergamo is an employer at Microlab Elettronica, which produces diagnostic medical devices

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Abstract

Introduction: The common belief about the beneficial effects of water immersion on leg veins function is mostly based on empirical experiences. We have performed a series of tests to evaluate the real effects of the increase of interstitial pressure generated by water immersion on the leg veins morphology, venous return and veno-lymphatic drainage.

Methods: The immediate effects of water hydrostatic pressure (wHP) on vein morphology and venous flow were evaluated by underwater duplex sonography (DS) during immersion. The immediate effects of HP on calf volume and ejection fraction (EF) were evaluated by underwater strain gauge pletysmography (SGP). The effects of prolonged immersion on leg volume and on subcutaneous tissues were evaluated by both water displacement volumetry (WDV) and DS.

Results: The caliper of normal and varicose veins were immediately and significantly reduced by immersion (p.004 and p 0.012 for the femoral and great saphenous veins, respectively). Simultaneously, the spontaneous centripetal flow increased. In varicose legs, the reflux was reduced or even disappeared. SGP demonstrated an immediate reduction of the calf circumference and the simultaneous increase of the EF (+68.9%). Finally, a marked reduction in ankle circumference (-2.89%), subcutaneous tissue thickness (-24.35%) and leg volume (-4,2%) was demonstrated after 30' of standing into the water. Walking into the pool for the same time resulted in an even more significant reduction of all these three parameters (-5.98%; -32.66% and -6.50%, respectively).

Discussion: our results suggest that the wHP-related reduction of vein caliber is responsible for the immediate increase of the centripetal flow, the immediate reduction of the calf volume and of the reduced reflux, when present. The great reduction of the leg volume after prolonged static immersion seems to be due to the positive effects of wHP on the balance between interstitial fluid filtration and lymphatic reabsorption. A mutual enhancement between the effects of HP on interstitial fluids dynamics and those of muscle activity on EF, may explain the greater reduction of the leg volume, ankle circumference and epifascial thickness after underwater walking compared to those after static immersion.

Conclusions: The possible clinical and rehabilitative implications of these findings in the treatment and rehabilitation of leg venous disorders are finally outlined.

Keywords hydrostatic pressure, venous return, fluid reabsorption, water displacement volumetry, underwater sonography

Introduction

The immersion into a pool or into the sea is anecdotally considered beneficial for the blood return and ascribed to the water Hydrostatic Pressure (wHP). The beneficial effects of balneotherapy in patients with Chronic Venous Disorders (CVD) is based on patient's reported improvement of symptoms and quality of life[1,2].

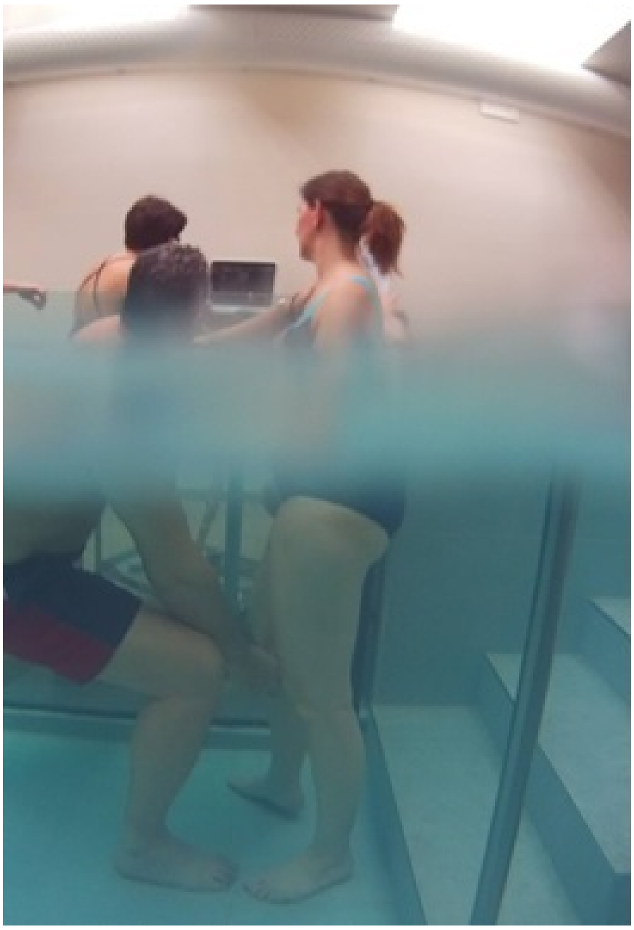

Fig. 1 - The technique for underwater sonography.

Until 2018 no study had objectively evaluated and assessed the direct effects of wHP on the leg venous system by means of modern techniques of investigation. A recent Cochrane review highlighted the need for evidence-based data on the effect of balneotherapy in CVD legs[3]. In their conclusions the Authors recommended to standardize measurements of outcomes.

Our studies started in December 2017 and were designed to directly evaluate the effects of wHP: a) on the vein morphology and flow, b) on the leg volume and c) on tissue morphology during immersion[4-6]. In particular, the steps of the research were:

- 1. To evaluate the morphology and flow of the leg veins during immersion by Duplex Sonography (DS)[4].
- 2. To evaluate the changes of the calf volume immediately after immersion and during walking into the pool by Strain Gauge Plethysmography (SGP)[5].

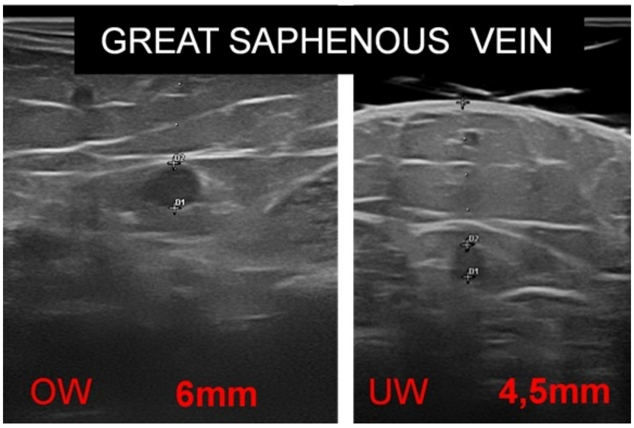

Fig. 2 - The caliber of a Great Saphenous Vein out of the pool (OW) and during immersion (UW).

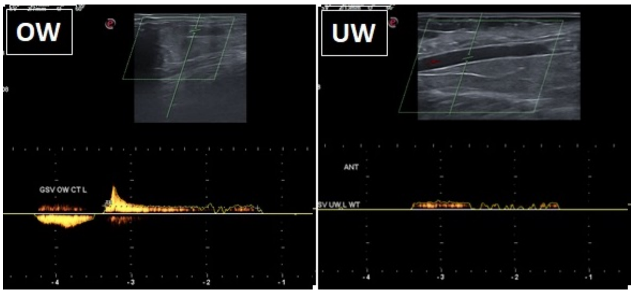

Fig. 3 - Reflux in the GSV on ground (OW) and after immersion into the pool (UW).

- 3. To evaluate the changes of the leg volume and of the thickness of the epifascial plane (skin plus subcutaneous layer) after prolonged immersion and prolonged walking into the pool by water displacement volumetry (WDV) and DS respectively[6].

The aim of this article is to report and summarize our experiences.

Methods

Immediate effects of immersion on leg veins morphology and flow (Underwater sonography of leg veins)[4].

Vein morphology and flow were evaluated in healty and varicose legs in standing position out of the pool and immediately after immersion (Fig 1).

Table I
Changes of Vein caliber (mm) after immersion

		median (mm)	p (Wilcoxon)
Femoral Vein	On ground	10.7	.004**
	Underwater	9.8	
Popliteal Vein	On ground	9.9	.008**
	Underwater	8.3	
Thigh GSV	On ground	5.6	.045*
	Underwater	5.0	
Knee GSV	On ground	4.9	.012*
	Underwater	4.4	

The diameter of the femoral (FV) and great saphenous veins (GSV) were measured at upper thigh. The diameter of the popliteal (PV) was measured at upper leg. The spontaneous blood flow and valves competence were evaluated in the FV and GSV at the upper thigh.

One side of the pool (water level 110) was assembled by a tempered crystal glass to see the screen of the Duplex machine when operating during immersion. No gel application was used during underwater DS, thank to the ultrasound transmission properties of the water.

Immediate effects of immersion on leg volumes (Underwater strain gauge pletysmography)[5]

The SGP probes were modified to make them water-proof. Venous volume (VV) in standing position and expelled volume (EV) after 20 steps were assessed by means of SGP before and after immersion in the same pool. Ejection fraction (EF) was calculated according to the well-established formula[3] $EF=100\times\frac{EV}{VV}$.

Effects of prolonged immersion and underwater walking on leg volume and epifascial thickness[6]

Leg volume was measured by WDV. Ankle circumference was measured by tape 5 cm above the medial malleolus. In order to get a consistent measurement site it was indelibly marked on the skin. At the same site the thickness of the epifascial layer (skin + subcutaneous layer) was measured by Ultrasonography.

The leg volume, ankle circumference and epifascial thickness were measured in subjects with occupational edema in the evening of three consecutive days after 30’ of standing into the pool, after 30’ of walking into the pool and after 30’ of walking out of the pool.

Results

Immediate effects of immersion on leg veins morphology and flow (Underwater sonography of leg veins)[4]

Underwater DS allowed an effective assessment of the superficial and deep veins morphology and flow. During immersion, the caliber of the deep and superficial veins were significantly reduced in normal and varicose limbs (Fig 2) (Table 1) with a marked increase of spontaneous centripetal flow. Similarly the diameter of the varicose veins was significantly reduced and a significant reduction or disappearance of reflux was also observed (Fig 3).

Immediate effects of immersion on leg volumes (Underwater strain gauge pletysmography)[5]

The volume of the calf evaluated by SGP in standing position significantly decreased immediately after immersion (-2%) (Fig 4). The reduction of calf volume after immersion was greater than that evaluated on ground by limb elevation. Walking in the pool further decreased the calf volume to -1.7%, leading to a measurable increase of EF of 68.9%.

Effects of water temperature on vascular response to immersion

The water temperature was much higher than that out of the pool and ranged around 32°-33°, that is the mean water temperature of rehabilitative pools. In order to discriminate the effects of wHP on vein size and flow from those due to temperature-related venous sympathetic tone, the effects of immersion were also evaluated during body immersion at progressive depths by multiple Duplex evaluations while the patients descended the pool stair.

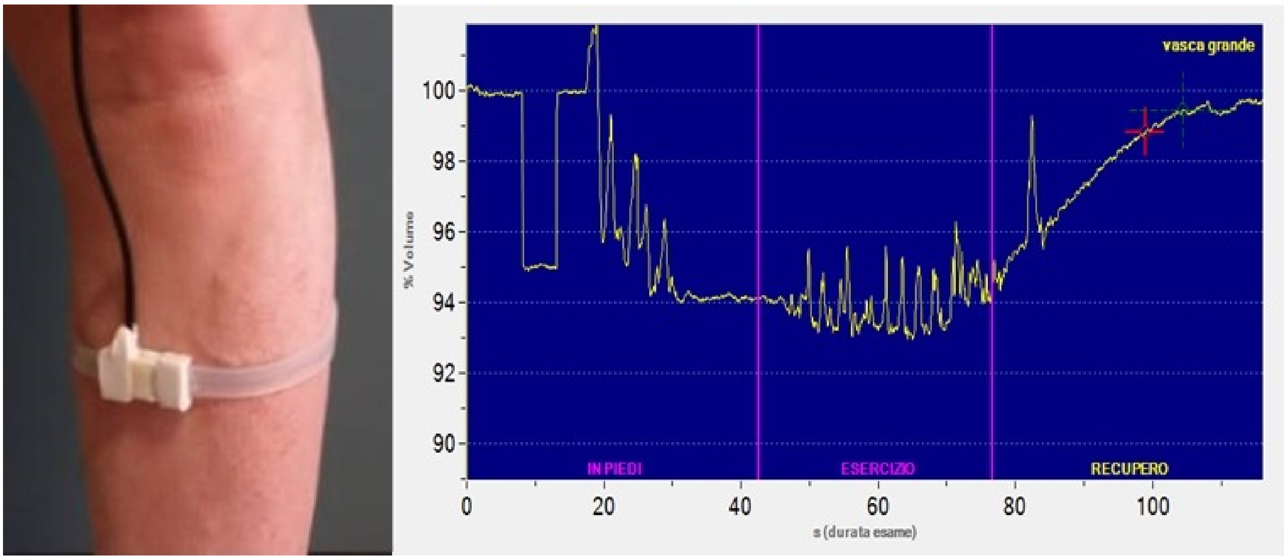

Fig. 4 - On the left, the water proof SGP probe. On the right side the normalized SGP findings in a leg with CVD during immersion.

Table II
Estimated water-HP and venous-HP (cmH_2O)
in a 175 cm tall subject, right atrium at 120 cm, immersed in a pool (water level 110 cm)

	wHP	vHP	wHC/vHP ratio
Mid thigh	29.42	54.43	54 %
Mid calf	58.85	69.98	84 %
Plantar veins	80.9	93.30	86 %

The reduction of veins caliber was progressive and correlated to the increasing depth of the water. This allowed to state that the immediate vascular response to water immersion (WI) was not due to the water temperature.

Effects of prolonged immersion and underwater walking on leg volume and skin thickness[6]

WDV demonstrated that 30' of immobile standing immersion resulted in a significant reduction of leg volume (-4.20%). Walking into the pool for 30' produced a more consistent reduction of the leg volume (-6,50%) whereas a reduction of leg volume after walking on ground did not occur. Ankle circumference and epifascial thickness showed a similar beaviour: ankle circumference was reduced by 2.89% and by 5.98 after 30' of immobile underwater standing or walking. The reduction of epifascial thickness after walking (-32.66%) was significantly greater than that after immobile underwater standing (-24.35%; p=0.009). Walking on ground for 30' did not result in a significant variation of both ankle circumference and epifascial thickness that remained basically unchanged.

Discussion

On underwater sonography

Underwater DS of leg vessels was firstly performed in our study[4]. We demonstrated that WI elicits an immediate diameter reduction of all deep and superficial, normal or varicose veins. Diameter reduction is accompanied by an increase of centripetal flow and by the reduction of reflux in varicose legs[4]. This was the first study to have objectively demonstrated the positive effects of water compression on vein morphology and venous return in normal and varicose limbs.

On underwater SGP

We demonstrated the feasibility of computerized SGP in underwater conditions and its ability to assess the leg VV and EF during immersion into a pool[5]. Our underwater SGP findings demonstrated a great reduction of leg volume immediately after the immersion, greater that that obtained on ground by leg elevation. The leg volume further decreased during a short walking into the pool due to an EF increase.

As bones and muscles volume cannot be reduced and soft tissues volume cannot be influenced by few seconds of immersion, we concluded that the immediate limb volume reduction after WI demonstrated by SGP, is entirely due to the reduction in size of the veins caused by wHP. This positively correlated with previously described DS findings.

Effects of prolonged immersion and underwater walking on leg volume and skin thickness

The significant reduction of the leg volume, ankle circumference and epifascial thickness after immobile standing is due to the water Hydrostatic Pressure (wHP) of about 81 mmHg at the bottom of a pool with a water level of 110 cm. (Table 2)

Actually, prolonging the immersion, the wHP squeezes the soft tissues of the leg, mainly the subcutaneous layer and its interstitial fluids, as demonstrated by epifascial tissues narrowing.

The greater reduction of leg volume resulting after prolonged underwater walking is due to the mutual enhancement of the effects of wHP and muscle pumping on venous hemodynamics and veno-lymphatic reabsorption. Both wHP and muscular pumping should improve the peripheral lymphatic drainage by forcing the interstitial fluid into the lymphatic vessels[7].

In fact, it was shown that the compression-related increase of tissue pressure increases the tension on the anchoring filaments of the initial lymphatics. The effects of the rhythmic autonomous contractions of the lymphatic collectors should be further enhanced by muscular activity.

Conclusions

Our studies clearly demonstrated for the first time the influence of wHP on veins diameter and flow, on static and dynamic leg volume and on the thickness of the epifascial layer[4-6].

The results of these preliminary studies agree with the common belief that immersion into the water improves venous return. As a matter of fact, our findings demonstrated that WI reduces the diameter of normal and varicose veins and increases the spontaneous flow. In varicose limbs, the reflux in the saphenous and tributary veins markedly decreases after immersion. These phenomena are likely due to the wHP that counteracts the pressure exercised by the column of blood on the leg vessels and microvessels.

In addition, our studies confirm the common belief that WI is an ideal model of compression of edematous legs. Actually, even if wHP in our study was much higher than that exerted by stockings or bandagings, it is effective and well tolerated because unnoticed at all.

WI was introduced since 1999 to reduce leg edema in pregnant women[8,9] but poorly investigated in the case of veno-lymphatic leg swelling[10-13].

We are currently evaluating the possible implication of our findings in the rehabilitation of patients with venous and lymphatic disorders[14]. In fact, the protocol we adopted in subjects with occupational edema is based on simple walking in water and feasible also by patients with neuromuscular or osteoarticular comorbidities.

Main criticisms

Further studies are necessary to better identify the mechanisms of action of wHP and to compare the effect of balneotherapy with other modalities of mechanical treatment of leg edema.

The amount and duration of clinical effects of a complete balneotherapy treatment need also to be evaluated.

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